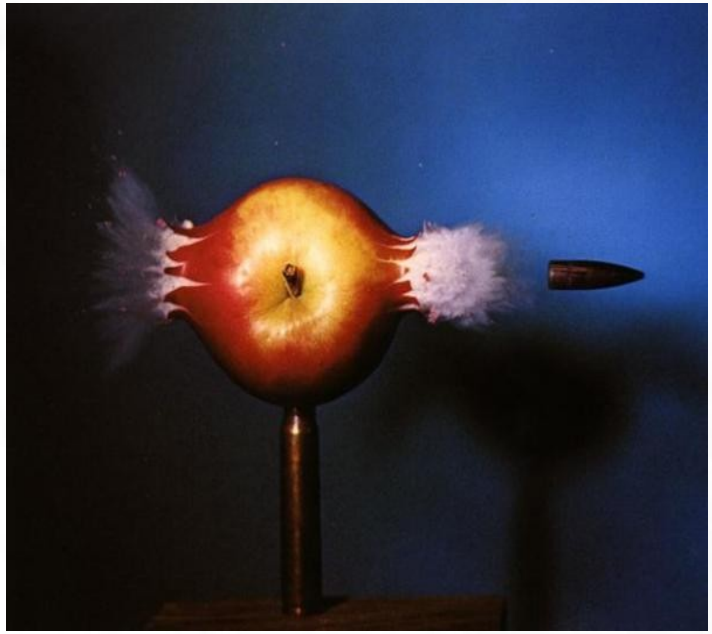
Conservation of momentum



Bullet
High speed
Low mass
Momentum = mV

Bullet +head
Low speed
High mass

Fluid, brain
Low speed, low mass

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DEFINITION OF LINEAR MOMENTUM

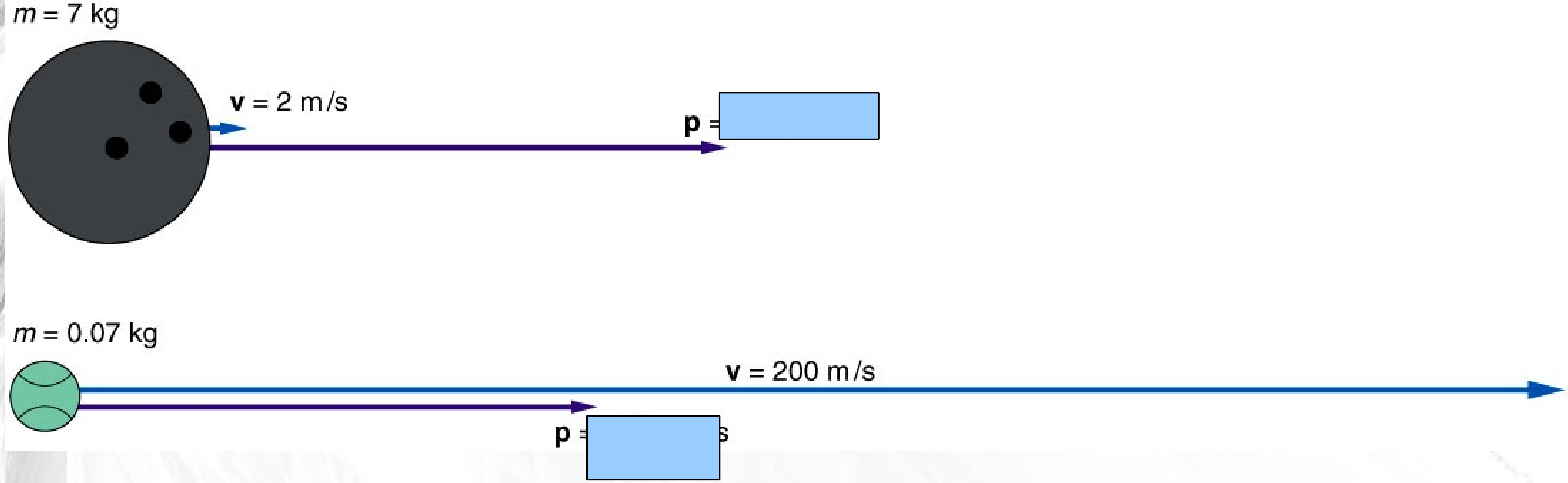
The linear momentum of an object is the product of the object's mass times its velocity:

$$\vec{\mathbf{p}} = m\vec{\mathbf{v}}$$

Linear momentum is a vector quantity and has the same direction as the velocity. We just say momentum

UNITS: kilogram $\cdot$ meter/second (kg $\cdot$ m/s)

Reference: -The physics of everyday phenomena: a conceptual introduction to physics by W. Thomas Griffith, McGraw-Hill
-Conceptual Physics by Paul Hewitt



COMPARE THE MOMENTUM of the bowling ball and the momentum of the tennis ball

Same momentum =

Same wallop.

Linear momentum, cont'd

- Momentum is a measure of an object's state of motion.
  - Consider an object whose momentum is 1 kg·m/s
    - This could be a 0.005 kg bullet traveling at 200 m/s.
    - This could be a 0.06 kg tennis ball traveling at 16.7 m/s.

1. A bowling ball has a mass of 6kg and a speed of 1.5m/s.
A baseball has a mass of 0.12kg and a speed of 40m/s
Which ball has the larger momentum.

2.What is the momentum, of a 1200kg car traveling with a speed of 27m/s (60mph)
(momentum = mass x speed. The momentum quantifies the motion)

In classical mechanics, linear **momentum** or translational **momentum** (pl. momenta; SI unit kg m/s, or equivalently, N s) is the product of the mass and velocity of an object.

Momentum - Wikipedia, the free encyclopedia
https://en.wikipedia.org/wiki/**Momentum** Wikipedia

$p = mv$ is the momentum

Δp is the change in momentum

$\Delta p = m\Delta V$

To change the momentum= apply an impulse J

Apply an impulse = change the momentum

$$F\Delta t = \Delta p$$

Impulse = change in momentum

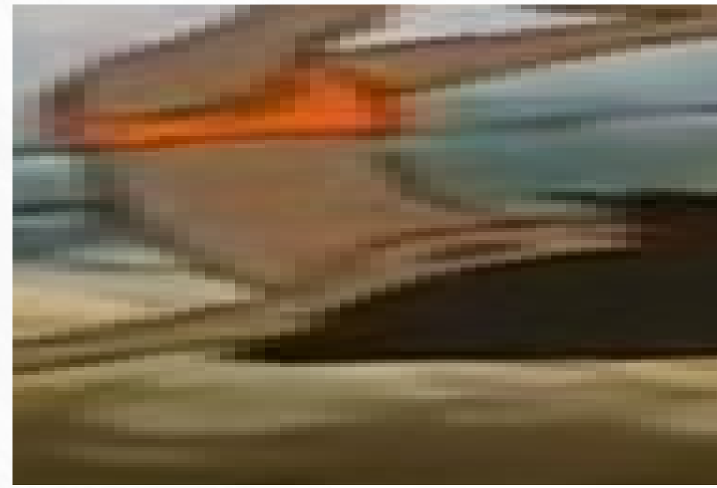
$$\Delta p = m\Delta V$$

(Final momentum – initial momentum) = mass x (final velocity-initial velocity)

$$p2-p1 = m\,(V2-V1)$$

CONSERVATION OF MOMENTUM ?

When 2 objects " collide" (interact)→
Momentum lost by one object = momentum gained by the second object (we neglect friction, air resistance).
This is because action = - reaction.



They both feel the same force
But the consequence is not the same. Consequence
Depends on mass

Divide by time ↓

$$M\, a = F = - m\, a$$

$$M\, \Delta V = - m\, \Delta V$$

Momentum lost by Balloo = momentum gained by Mowgli

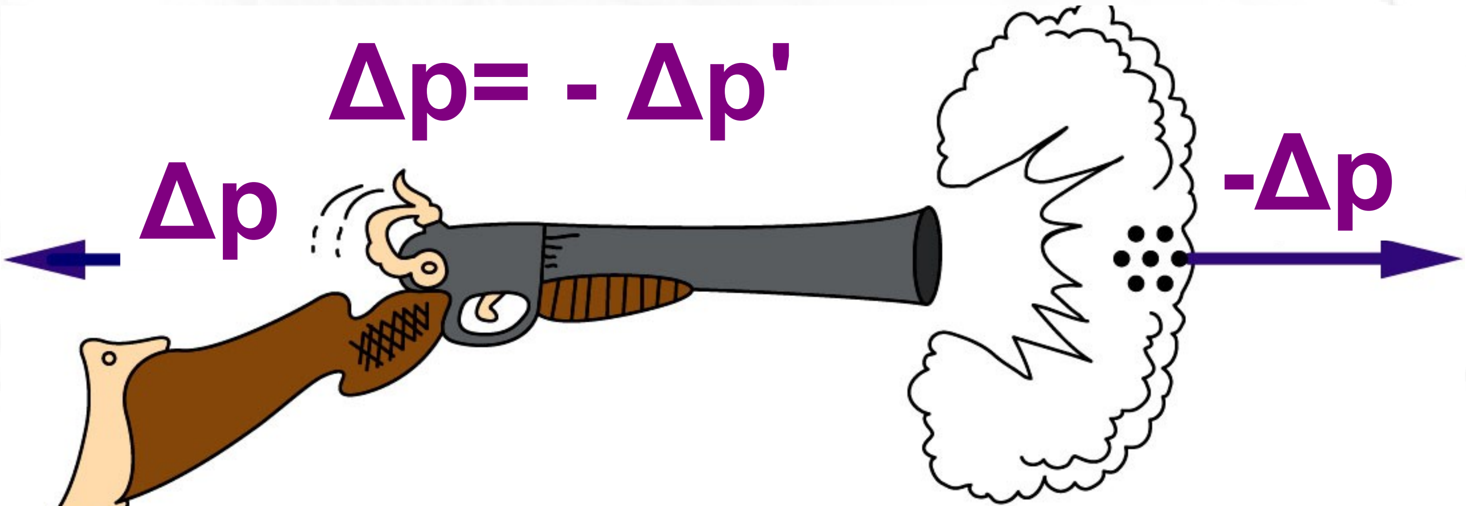
$$m\,a = F = M\,a$$

divide by Δt

$$m\,\Delta V = F\Delta t = -\,M\,\Delta v$$

This means : $M\,\Delta v = -\,m\,\Delta V$

Demo:
cars

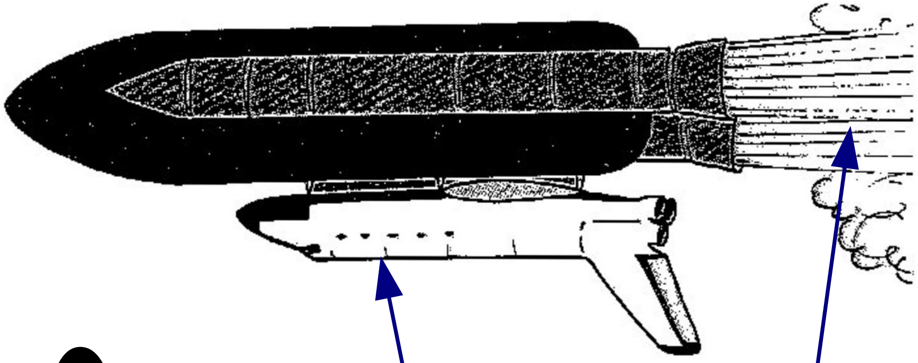


http://faraday.physics.utoronto.ca/PVB/Harrison/Flash/ClassMechanics/AirTrack/AirTrack.html

During a “ collision” or interaction between 2 objects:
MOMENTUM LOST by 1 object is GAINED by the other one.
This is the conservation of momentum. This is how rockets work.

Conservation of momentum is from:
Newton's third law.
Action = reaction , forces come in pair

When 2 objects interact
The force is the same but not the change
In velocity.



$$\Delta p1 = -\Delta p2$$

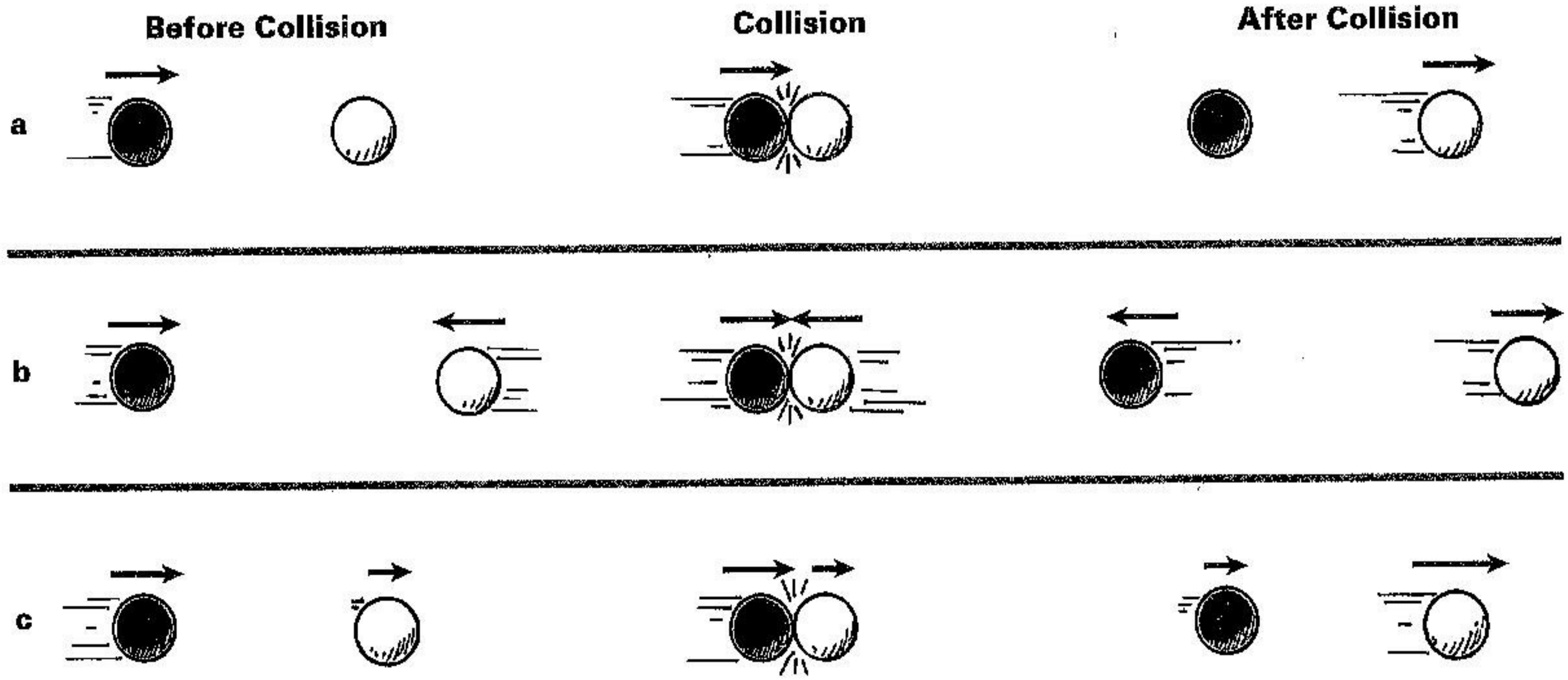
$$M\frac{\Delta v}{\Delta t} = F = -m\frac{\Delta V}{\Delta t}$$

$$M\Delta v = F\Delta t = -m\Delta V$$

$$\Delta p1 = -\Delta p2$$

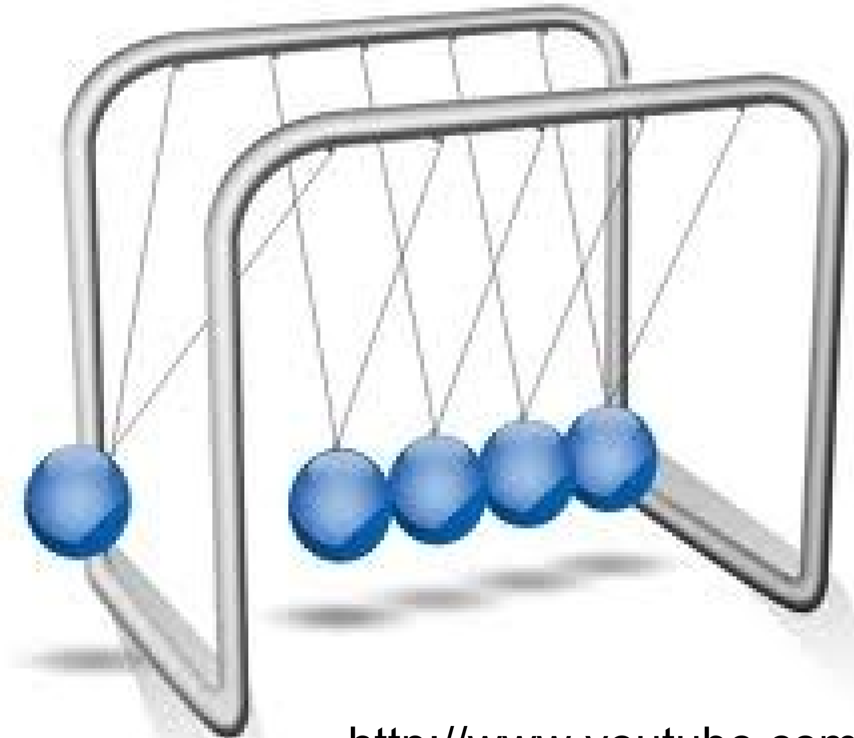
Change momentum of shuttle = - change momentum of gas
1 object loses momentum, 1 object gains momentum

Elastic collision = hit and bounce / hit and stop / hit and transfer momentum
We suppose the mass the same does not have to be the case.
The momentum lost by 1 object = momentum gained by the second object



Describe each collision. Is the momentum transferred from one ball to the other ?
Is the momentum totally transferred or partially ?
Or is the momentum exchanged ?
Note: the collisions are said to be elastic. The total energy is conserved.
The ball don't undergo change in shape at the end.

demo



http://www.youtube.com/watch?v=4IYDb6K5UF8

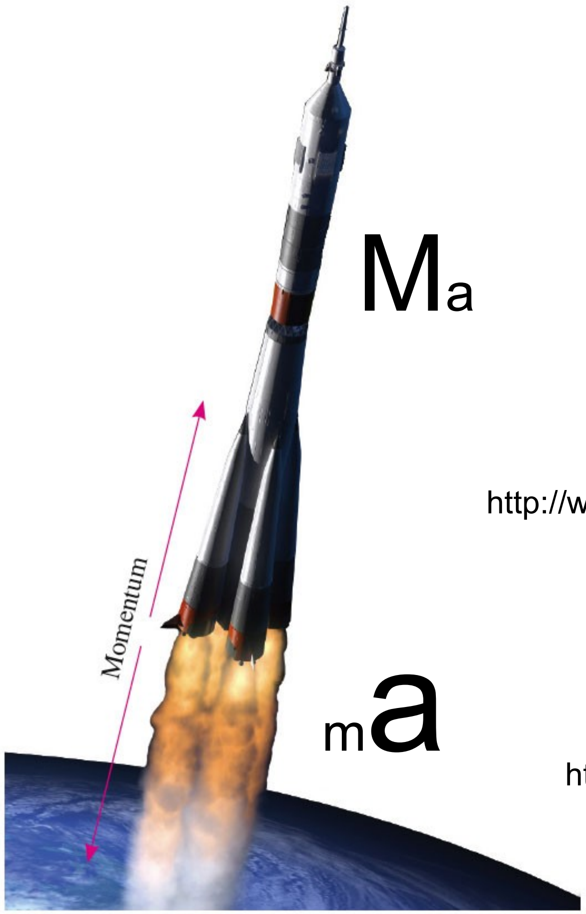
In space

http://www.youtube.com/watch?v=h3PUXbo3tCo&feature=player_embedded

Recoil from gun

Video :basketball +tennis ball

A ROCKET WORKS THE SAME WAY.



M_a

$_m a$

Conservation of momentum explains How a rocket work. This is a RECOIL SITUATION.

The rocket pushes on its own fuel.
The increases in speed is small
So you need a lot of fuel !!!

http://www.school-for-champions.com/science/newtons_cradle.htm#.VEUUGhb4rw4

http://www.walter-fendt.de/ph14e/collision.htm

http://onlinephys.com/cut3.jpg

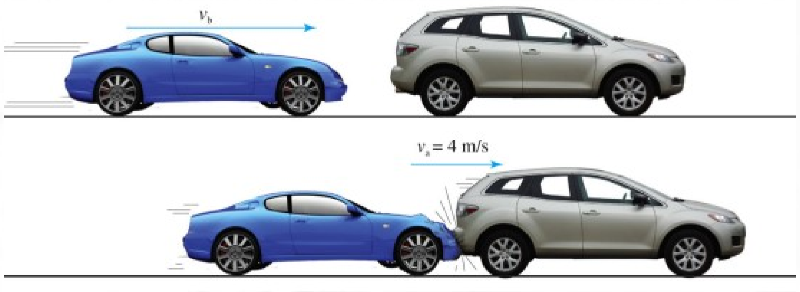
Ballistic pendulum demo

http://www.youtube.com/watch?v=MdwVrrnRaCE

http://www.youtube.com/watch?v=oNGm4mVWMuY

Conservation of linear momentum

for object 1 and object 2 colliding



- The **Law of Conservation of Linear Momentum** states:

  The total linear momentum of an isolated system is constant. (we neglect friction if time of impact small. And not external forces)

$$\Delta p1 = -\Delta p2$$

p1final – p1initial =-(p2final - p2initial)

Total momentum before = total momentum after

Conservation of linear momentum, cont'd

- We can write this as:

$$p_{before} = p_{after}$$

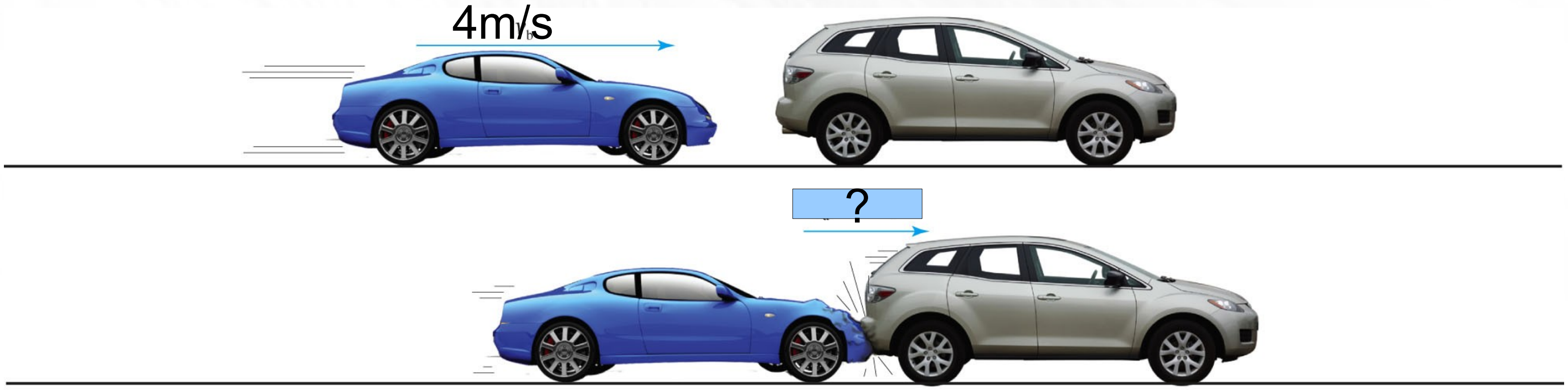
- To study a collision:
  - Add the momenta of the objects before the collision.
  - Add the momenta after the collision.
  - The two sums must be equal.

http://faraday.physics.utoronto.ca/PVB/Harrison/Flash/ClassMechanics/AirTrack/AirTrack.html

Example #1
hit and stick

A 1,000 kg car (car 1) runs into the rear of a stopped car (car 2) that has a mass of 1,500 kg. Immediately after the collision, the cars are hooked together.

The initial speed of car 1 is 4m/s. Whats the final speed V' ?

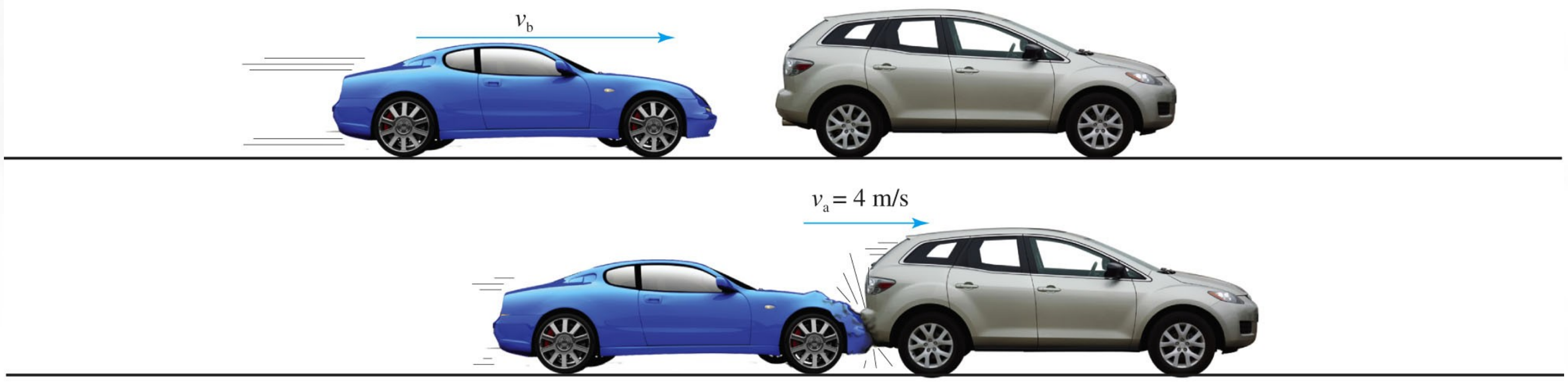


Use: total momentum before = total momentum after
Or m1V1i + m2V2i = m1V1f + m2V2f

1000(4) + 0 = 1000V' + 1500 V' → V' = 4000/1500 @ right

Example #2

A 1,000 kg car (car 1) runs into the rear of a stopped car (car 2) that has a mass of 1,500 kg. Immediately after the collision, the cars are hooked together and have a speed of 4 m/s. What was the speed of car 1 just before the collision?



Use: total momentum before = total momentum after

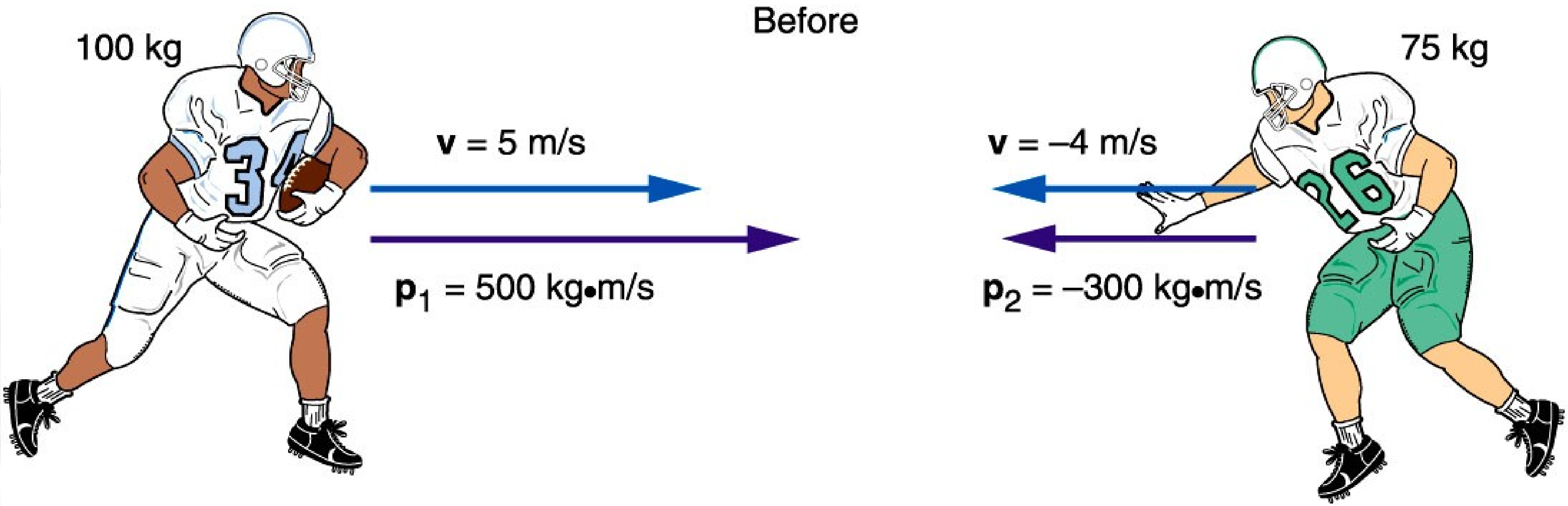
Or 1000V1 + 1500(0) = 1000(4)+ 1500(4)

1000 V1 = 2500(4)

V1=2.5(4) = 10 m/s

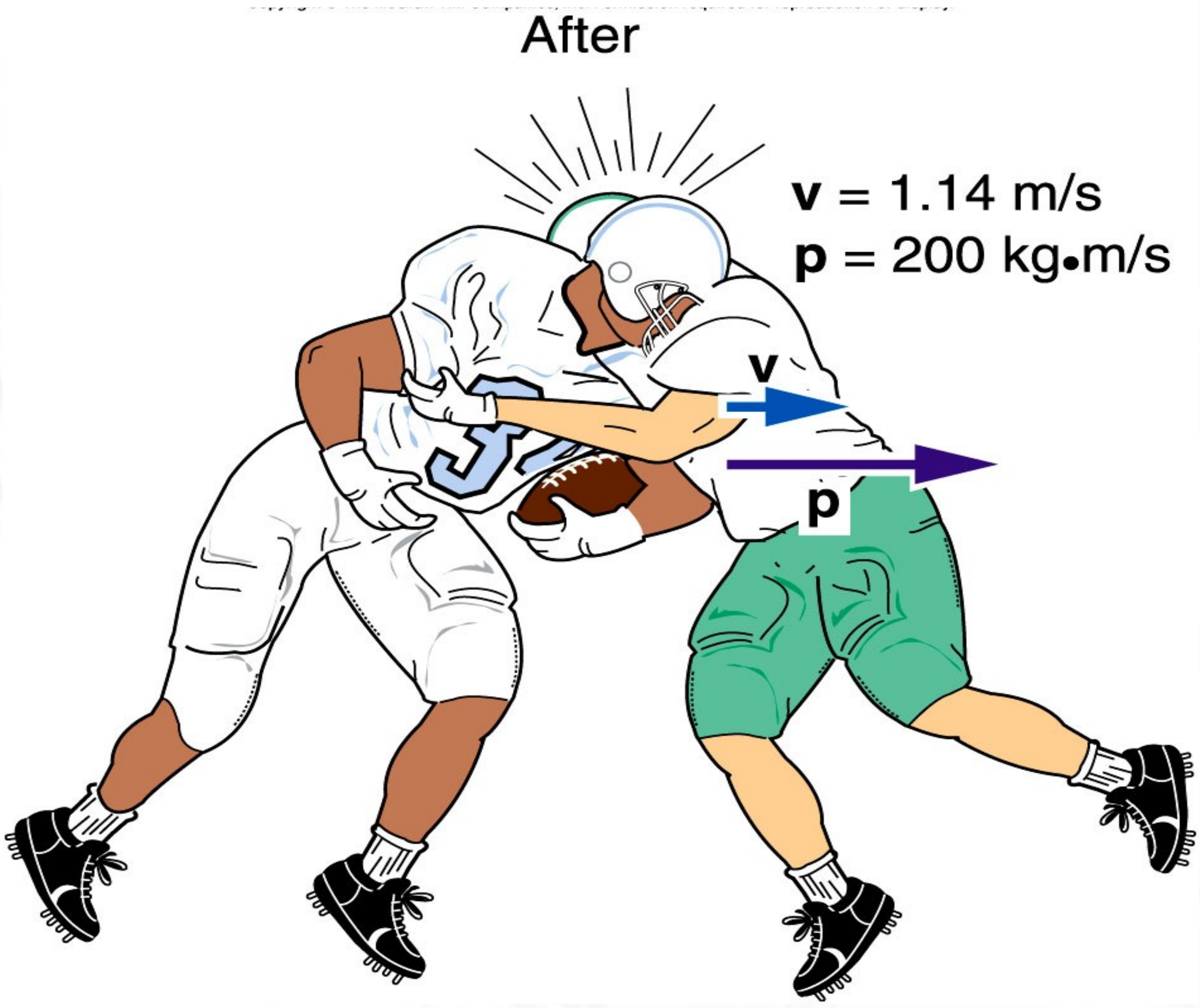
Note that in a " hit and stick" situation, kinetic energy Is not conserved. Compute the kinetic energy of the System before (1000kg@10m/s) and after (2500kg@4m/s) How much energy was lost ? What is the work done by the friction ?

Another example of hit and stick !!



THE 2 PLAYERS STICK TO EACH OTHER AFTER COLLISION

1) Find the FINAL VELOCITY (which way are they going)
2) the change of momentum for each player
3) the momentum before and after collision



Kinetic energy is not conserved.
Energy went to broken bones, bruises and heat and sound

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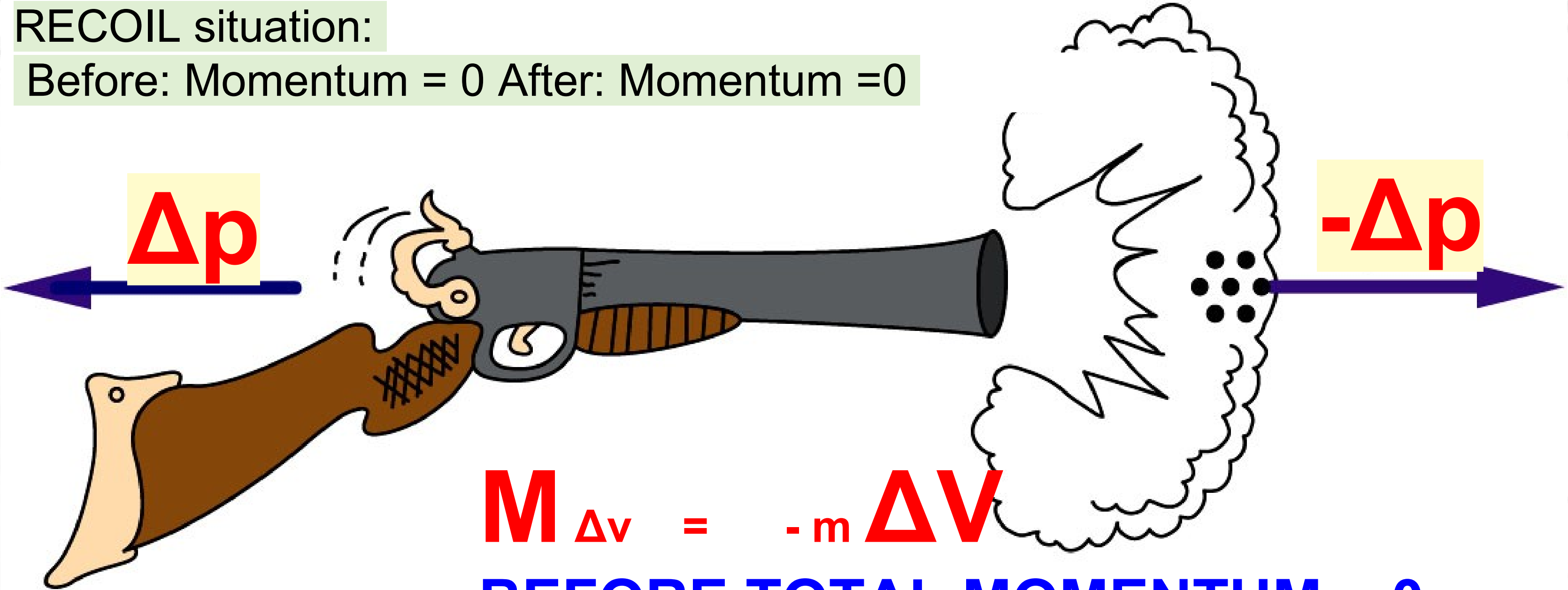
RECOIL situation:

Before: Momentum = 0 After: Momentum =0



M Δv = - m ΔV

BEFORE TOTAL MOMENTUM = 0

AFTER TOTAL MOMENTUM = 0

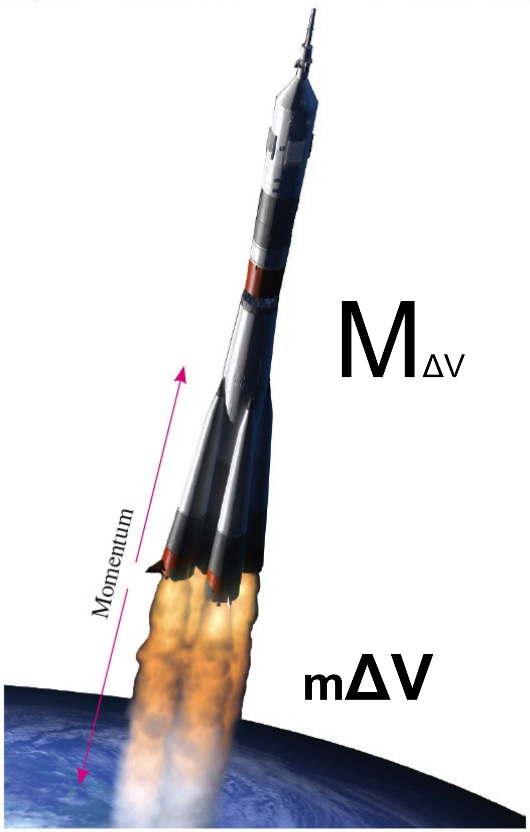
0 = p1 + p2

P1 = - p2   m1V1 = - m2V2

m2/m1 = - V2/V1

THE FORCE applied to the bullets and to the riffle is the same.
BUT which one undergo the larger acceleration ?
IS there a kick BACK ?
WHAT do YOU NEED to do so your shoulder DOES NOT BREAK ?

RECOIL:the rocket



This is a little more complex. The rocket loses mass from burning fuel.

The thrust comes from ejecting a mass Δm of fuel
During a time Δ(t)

Change in momentum of gas = thrust of rocket x Δ(t)
If the mass Δm of gas is ejected with a speed u
Then change in momentum = Δ(mu) = Δm u

So thrust x Δt = Δm u or thrust = u Δm/Δt

The thrust depends ho fast the fuel is ejected.

The equation is:
Thrust – mg = mass_rocket(t) x acceleration
But it needs to be integrated between initial and final time

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Recoil situation

MOMENTUM before = _____
The mass of granny =100kg
The mass of the girl = 50kg

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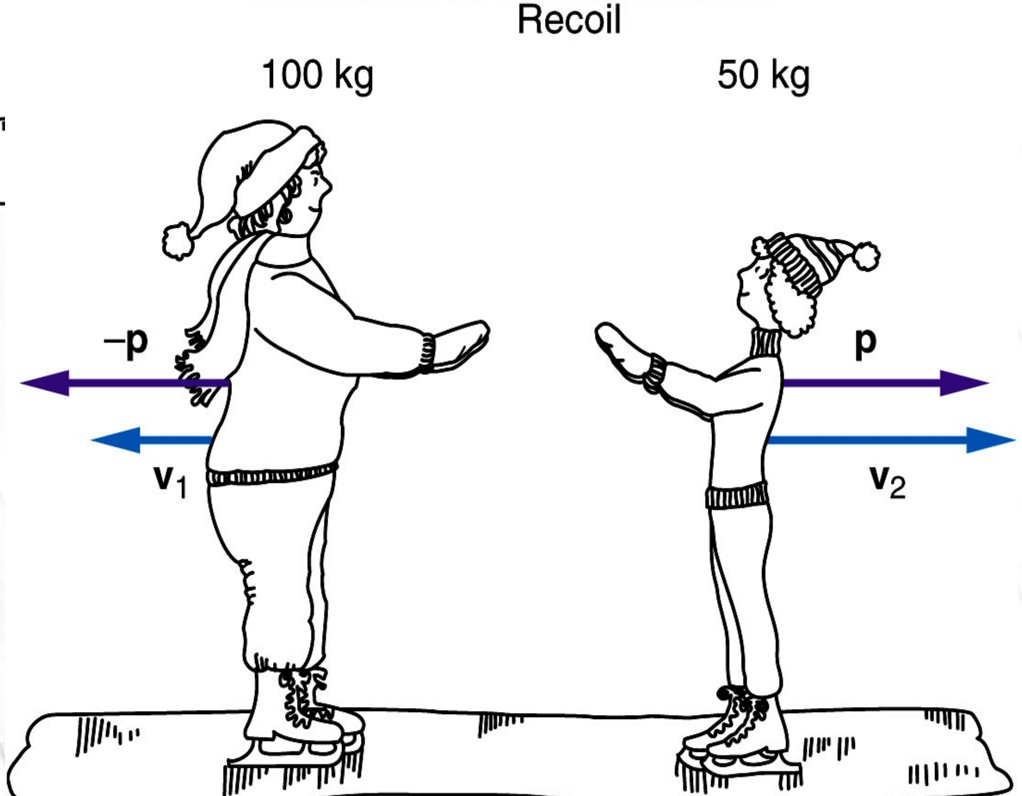
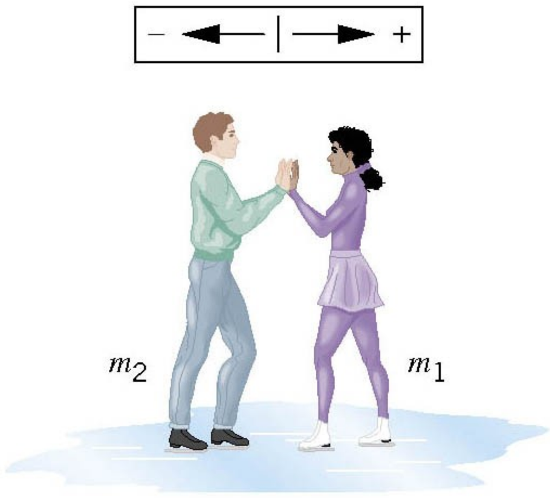


MOMENTUM after = ______
Compare the velocity of
Granny versus velocity of the girl

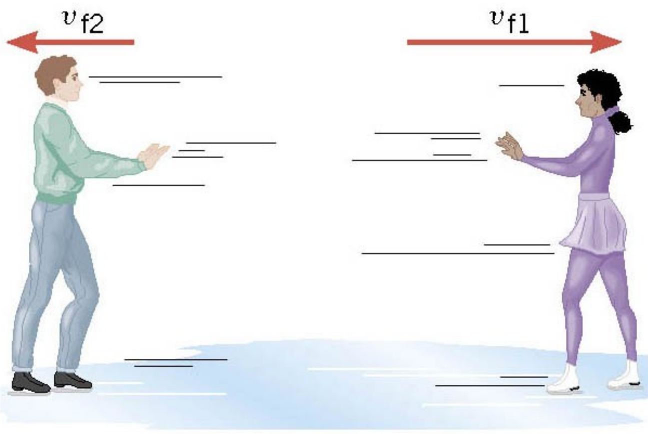
Example 6 Ice Skaters

Starting from rest, two skaters push off against each other on ice where friction is negligible.

One is a 54-kg woman and one is a 88-kg man. The woman moves away with a speed of +2.5 m/s. Find the recoil velocity of the man.



(*a*) Before



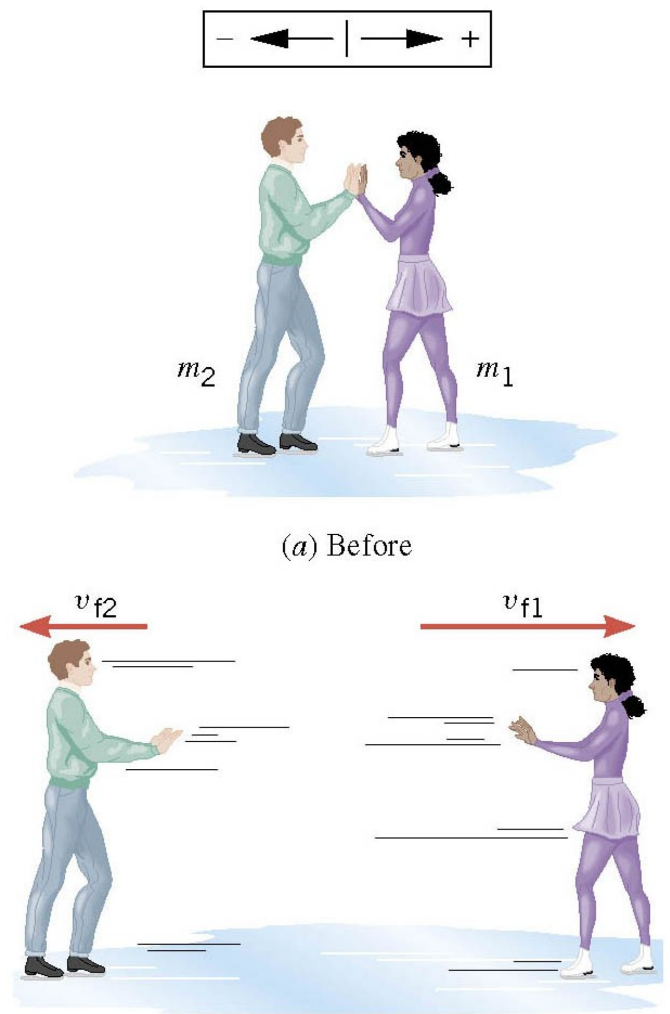
(*b*) After

$$\vec{\mathbf{P}}_{\mathbf{f}} = \vec{\mathbf{P}}_{\mathbf{o}}$$

$$m_1 v_{f1} + m_2 v_{f2} = 0$$

$$v_{f2} = -\frac{m_1 v_{f1}}{m_2}$$

$$v_{f2} = -\frac{(54\,\text{kg})(+2.5\,\text{m/s})}{88\,\text{kg}} = -1.5\,\text{m/s}$$



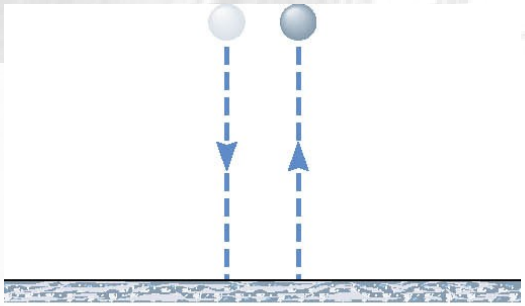
(*a*) Before

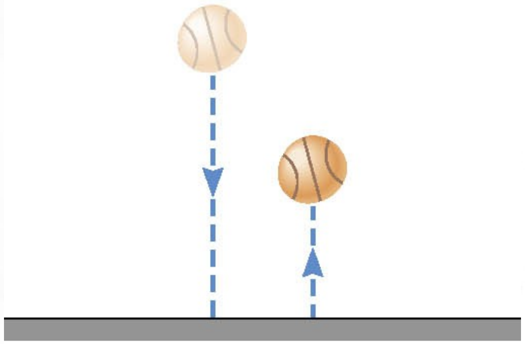
(*b*) After

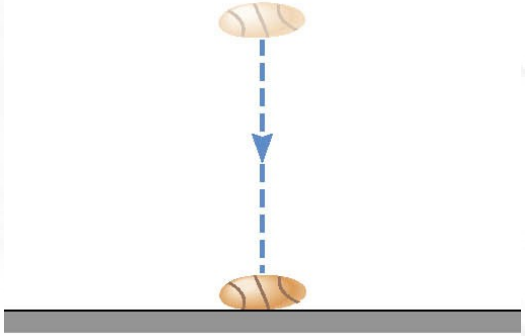
The total linear momentum is conserved when two objects collide, provided they constitute an isolated system.

Elastic collision -- One in which the total kinetic energy of the system after the collision is equal to the total kinetic energy before the collision.

Inelastic collision -- One in which the total kinetic energy of the system after the collision is *not* equal to the total kinetic energy before the collision; if the objects stick together after colliding, the collision is said to be completely inelastic.

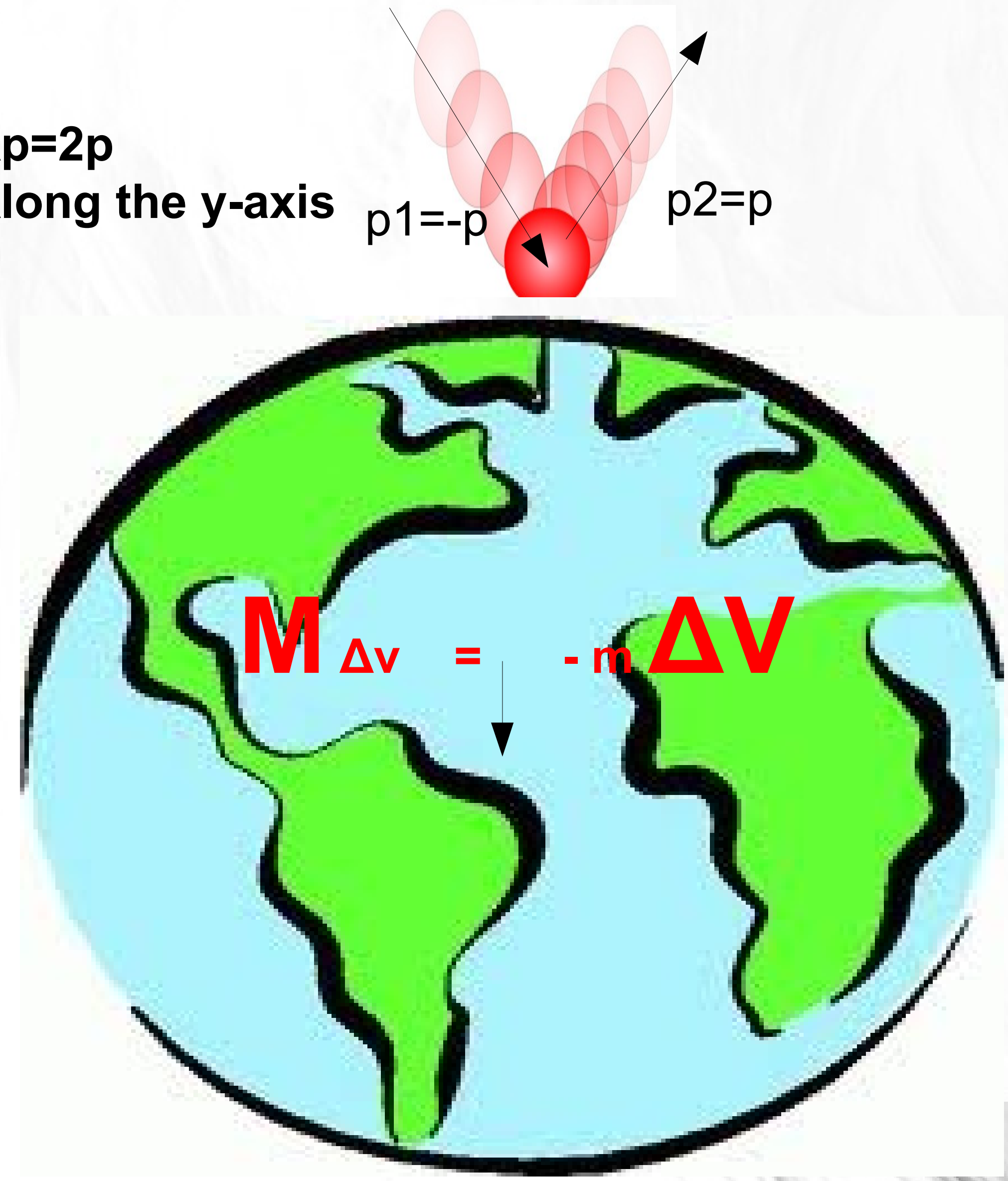

(a) Elastic collision


(b) Inelastic collision


(c) Completely inelastic collision

.m is the mass of the ball

$\Delta p=2p$
Along the y-axis

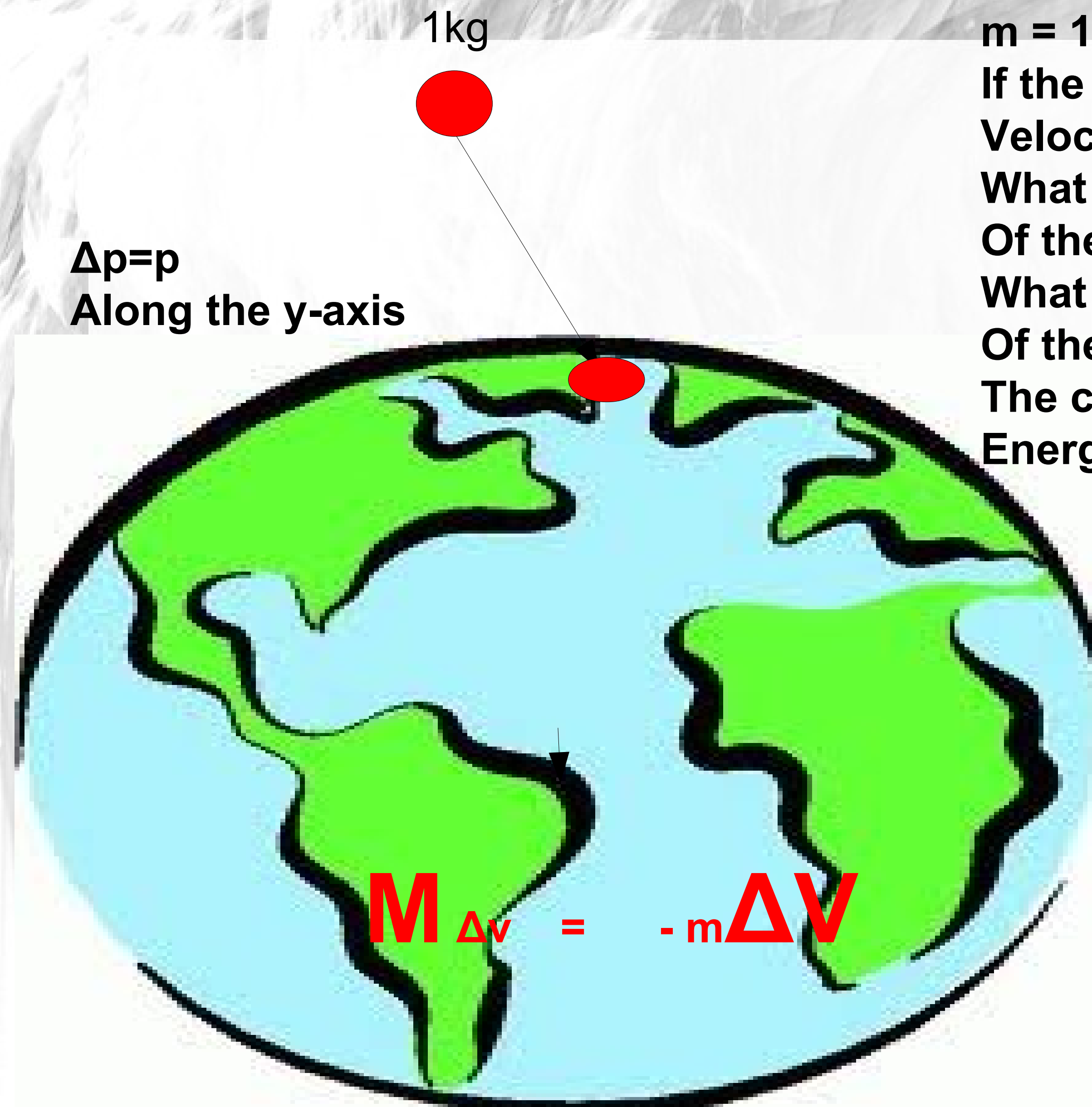


When a ball bounces off the Earth,
The ball gained momentum.
The velocity changes direction.
So if V 1 = -3 (initial)
And V2=3 (final)
That means the change in velocity
Is + 6 or the gain in momentum is
6m. **$\Delta p=+6m$ = gain.**
Than means that the Earth lost
Amount too. But because the mass
Of the Earth is huge, the change in
Its velocity is tiny.

$\Delta p=-M_{huge} \times \Delta v_{small} = -6m$

Note: the collision is elastic
So the kinetic energy is
Conserved. The kinetic energy
Is a scalar so the sign of the
Velocity does not matter:
$KE1 = 0.5\ m\ V1^2 = 0.5m(3)^2$
$KE2= 0.5\ m\ V2^2 = 0.5\ m\ (3)^2$
So KE2 = KE1
But p2 = - p1

$\Delta p = p$
Along the y-axis



m = 1kg . Velocity initial = -3m/s
If the ball does not bounce :
Velocity final = 0
What is the change of momentum Of the ball ?
What is the change of momentum Of the Earth ?
The collision is inelastic.
Energy is not conserved.

Note: the collision is inelastic So the kinetic energy is not Conserved.
$KE1 = 0.5\ m\ V1^2 = 0.5m(-3)^2$
$KE2 = 0.5m(0)^2$
Energy is lost to heat, sound, Deformation of the ball

1. A fullback with a mass of 100 kg and a velocity of 3.5 m/s due west collides head-on with a Defensive back with a mass of 80kg and a velocity of 6m/s due east. (in class)

A)What is the initial momentum of each player ?
B)What is the total momentum of the system before the collision?
C)If the stick together and external forces can be ignored , what direction will they be traveling Immediately after they collide ?

2. A Ice skater with a mass of 80kg pushed off against a second later with a mass of 32kg. Both Skaters are initially at rest.
A) What is the total momentum of the system after they push off ?
B) If the larger skater moves off with a speed of 3m/s, what is the corresponding speed of the smaller Skater ? (in class)

3. (HW) A rifle with a mass of 2.2kg fires a bullet with a mass of 5g(0.005kg) . The bullet moves with a Velocity of 600m/s after the rifle is fired !!! (1340 mph!!)
A)What is the momentum of the bullet after the rifle is fired ? (hint: recoil situation !)
B)If external forces acting on the riffle can be ignored, what is the recoil velocity of the rifle ?
(use: equation of recoil).

4.(HW)A rocket ship at rest in space gives a short blast of its engine, firing 50kg of exhaust gas out the bac
ends (the gas) with an average velocity of 400m/s What is the change of momentum of the rocket during the Blast? Hint: change of momentum of gas = change of momentum of rocket.
The gas has an initial speed of 0. (it is inside the rocket)/

5. in class.A rail road car with a mass of 12,000kg collides and couples with a second car of mass 18,000kg
That is initially at rest. The first car is moving with a speed of 12m/s prior to the collision.
A)What is the initial momentum of the first car ?
B)If external forces can be ignored, what is the final velocity of the 2 railroad cars after they couple ?

6.in classs. A fast ball thrown with a velocity of 40m/s (90mph) is struck by a baseball bat, and a line drive
Comes back toward the pitcher with a velocity of 60m/s. The collision is between the bat and the ball.
The ball is in contact with the bat for a time of just 0.04s. The baseball has a mass of 120g (0.12kg)

A) What is the change in momentum of the baseball during this process ?
Hint: (conservation means momentum lost by bat = - momentum gained by ball.
So compute the momentum Gained by the ball. Don't forget the negative sign for the bat).
B)What is the magnitude of the impulse required to produce this change in momentum ?
C) What is the magnitude of the average force that acts on the baseball to produce this impulse ?
(impulse = change in momentum)

7.HW. A bullet is fired into a block of wood sitting on a block of ice. The bullet has an initial velocity of 500m/s and a mass of 0.005kg. The wooden block has a mass of 1.2kg and is initially at rest.
The bullet remains embedded in the wood afterward. (so hit and stick situation)
A)Assuming that momentum is conserved, find the velocity of the block of wood and bullet after the Collision. (so momentum before = momentum. V1'=V2'=V')
B)What is the magnitude of the impulse that acts on the block of wood in this process ?
C)Does the change in momentum of the bullet equals that of the wood ?

8. in class. Consider 2 cases in which the same ball is thrown against a wall with the same initial velocity.
I case A, the ball sticks to the wall and does not bounce. In case B, the ball bounces back with the Same speed that it came in with.
A)in which of these examples is the change in momentum the largest ?
B)Assuming that the time during which the momentum change takes place is approximately The same for these 2 cases, in which case is the larger ravage force involved ?
C) is the momentum conserved in this collision?

9. (review. HW) A car traveling at a speed of 18m/s (40mpg) crashes into a solid concrete wall.
The driver has a mass of 90kg.
A)What is the change in momentum of the driver as he comes to a stop ? (V'=0)
B)What impulse is required in order to produce this change in momentum ?

10. (HW) A 1500kg car traveling due North with a speed of 25m/s collides head-on with a 4500kg Truck traveling due South with a speed of 15m/s. The 2 vehicles stick together after the collision
A)What is the total momentum of the system priori to the collision?
B)What is the velocity of the 2 vehicles after the collision ?

11.(HW)A4000kg truck traveling with a velocity of 10m/s due north collide head-on with a 1200kg car Traveling with a velocity of 20m/s due South. The 2 vehicles stick together after collision.
A)draw the situation (hit and stick)
B)What is the momentum of each vehicle prior to the collision ?
C)What are the size and direction of the total momentum of the 2 vehicles after they collide ?
(so p1+p2)

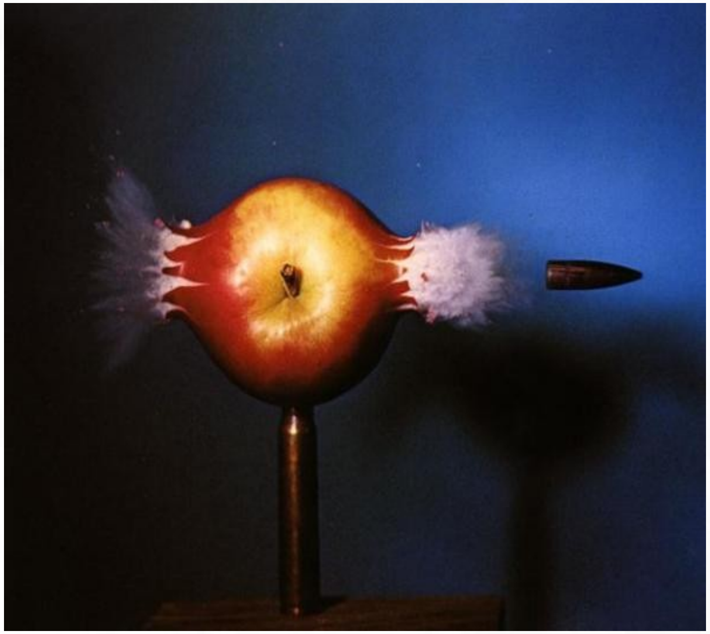
12.(skip) For the 2 vehicles in 11. Sketch to scale the momentum vectors of the 2 vehicles
A)Prior to the collision.
B)Add the 2 vectors on your sketch graphically.

The 35-kilogram girl is standing on a 20-kilogram wagon and jumps off, giving the wagon a kick that sends it off at 3.8 meters per second. How fast is the girl moving?

A 1.2-kilogram basketball traveling at 7.5 meters per second hits the back of a 12-kilogram wagon and bounces off at 3.8 meters per second, sending the wagon off in the original direction of travel of the ball. How fast is the wagon going?

A 2 000-kilogram limousine going east at 22 meters per second strikes a 1 200-kilogram sports car going west at 30 meters per second. How fast are the two cars going together after the collision?

Conservation of momentum



Bullet
High speed
Low mass
Momentum = mV

Bullet +head
Low speed
High mass

Fluid, brain
Low speed, low mass

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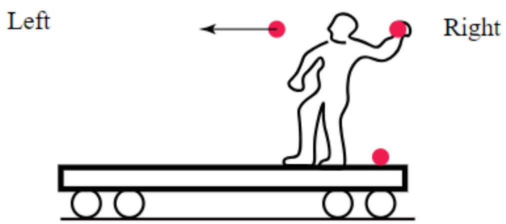
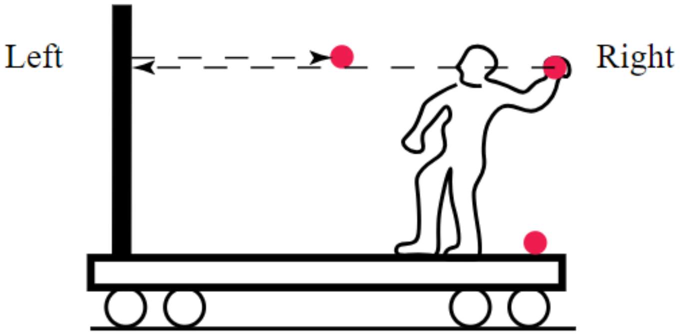


Suppose you are on a cart initially at rest on a frictionless track. If you start throwing balls towards the left, will the cart be put into motion?



Suppose you are on a cart which is initially at rest that rides on a frictionless track. You throw a ball to the left at a vertical wall that is firmly attached to the cart. If the ball bounces straight back as shown in the picture, will the cart be put into motion after the balls bounce back from the wall?

https://www.youtube.com/watch?v=bU4PoTuXg6
o

dance

PRINCIPLE OF CONSERVATION OF ANGULAR MOMENTUM

https://www.youtube.com/watch?v=NeXIV-wMVU
k

Walter Lewin

The angular momentum of a system remains constant (is conserved) if the net external torque acting on the system is zero.

http://www.youtube.com/watch?v=0k276y9kuQQ&feature=related
https://www.youtube.com/watch?v=NeXIV-wMVUk

(a) (b)

$$I_1 \, w_1 = I_2 \, w_2$$

About angular momentum

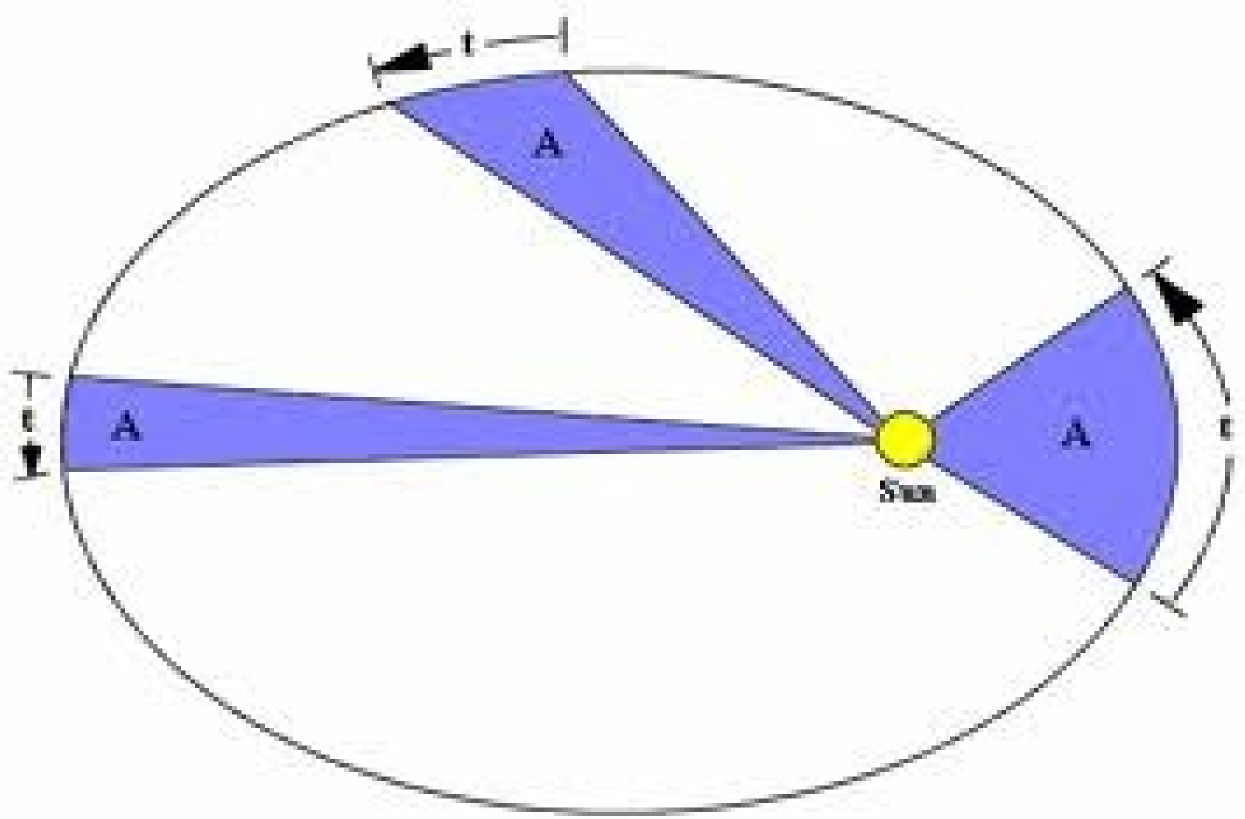
Angular momentum = mass x extension of mass X speed.

If you change the distribution of mass around the
Axis, the speed as to change since the angular
Momentum stays the same and the mass stays the
Same.

Same idea when water spirals down a drain
Faster and faster or when a disk of gas aggregates
To form a star or a sun with its planet.

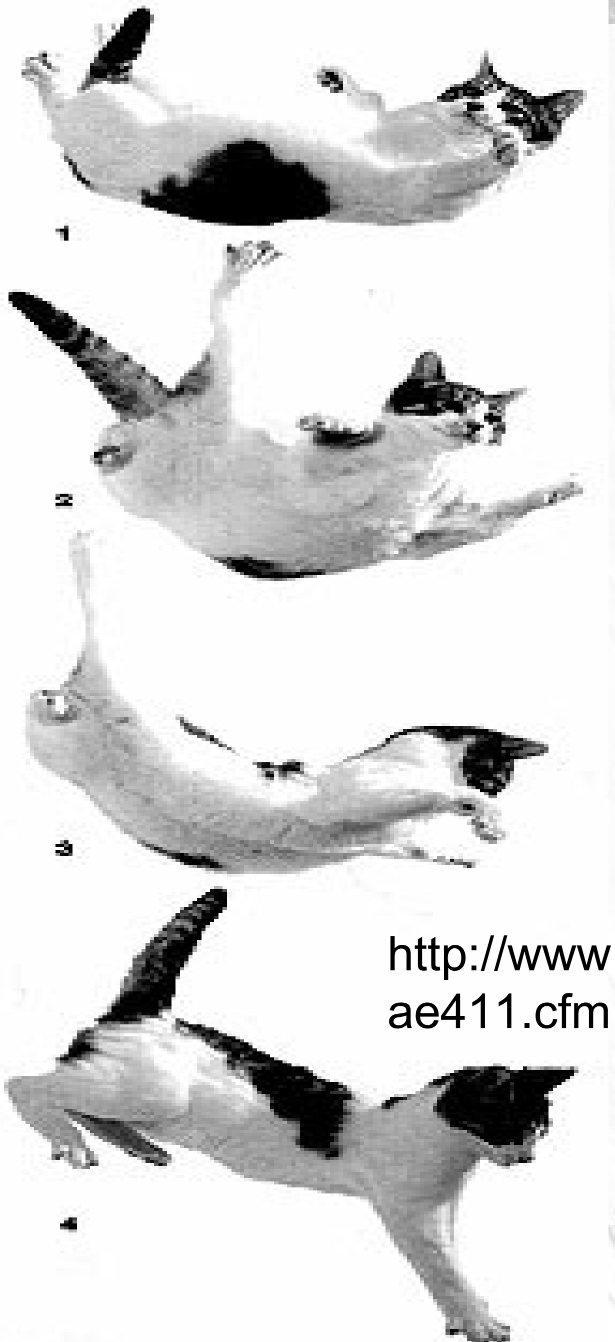
Planes moving along ellipses speed up when
They get closer to the Sun. (Kepler's second law)
So they cover the same area.

https://
www.youtube.com/
watch?v=EixtGKNP6ok



http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::800::600::/sites/dl/free/0072482621/78778/Kepler_Nav.swf::Keplers%20Second%20Law%20Interactive

Kepler’s second law: the planets sweep the same area during
The same amount of time.
It is a consequence of conservation of angular momentum.



The cat spins the tail in one direction
And the body spins the other way.

This is the conservation of momentum.

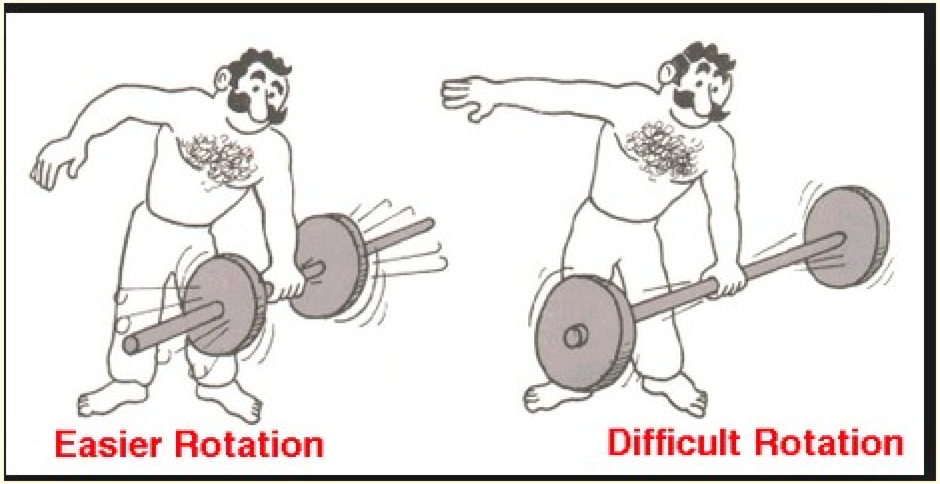
Same idea with astronauts.

http://richannel.org/the-physics-of-a-falling-cat

http://www.physlink.com/education/askexperts/ae411.cfm

CONSERVATION OF ANGULAR MOMENTUM

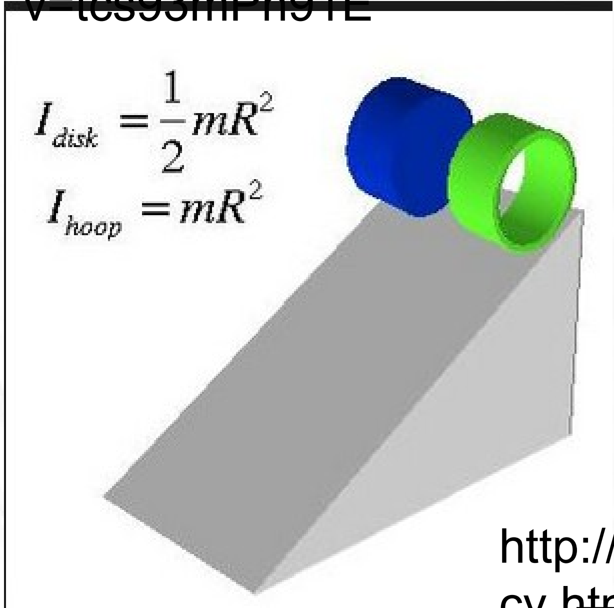
Angular momentum depends on the mass distribution about an axis and On the speed. If the distribution of mass is modified, the speed has to Change so the momentum stays the same.



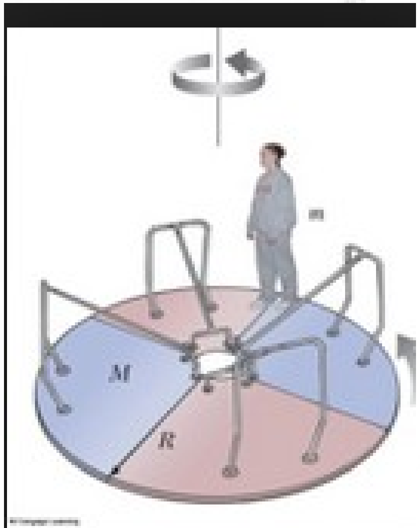
This happens during EQ or tsunami.

2010 a monster quake in Chile shortened the day by 1.26 millionths of A second so the Earth spins (slightly faster)

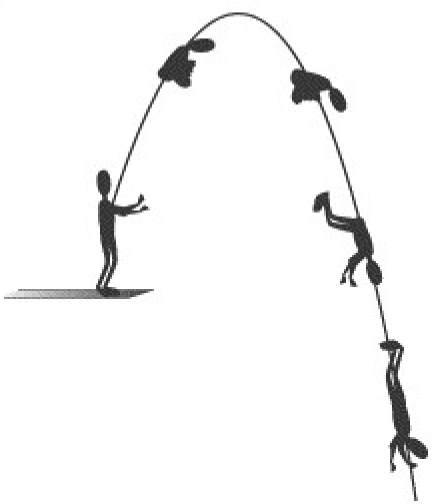
https://www.youtube.com/watch?v=tcs93mPn91E

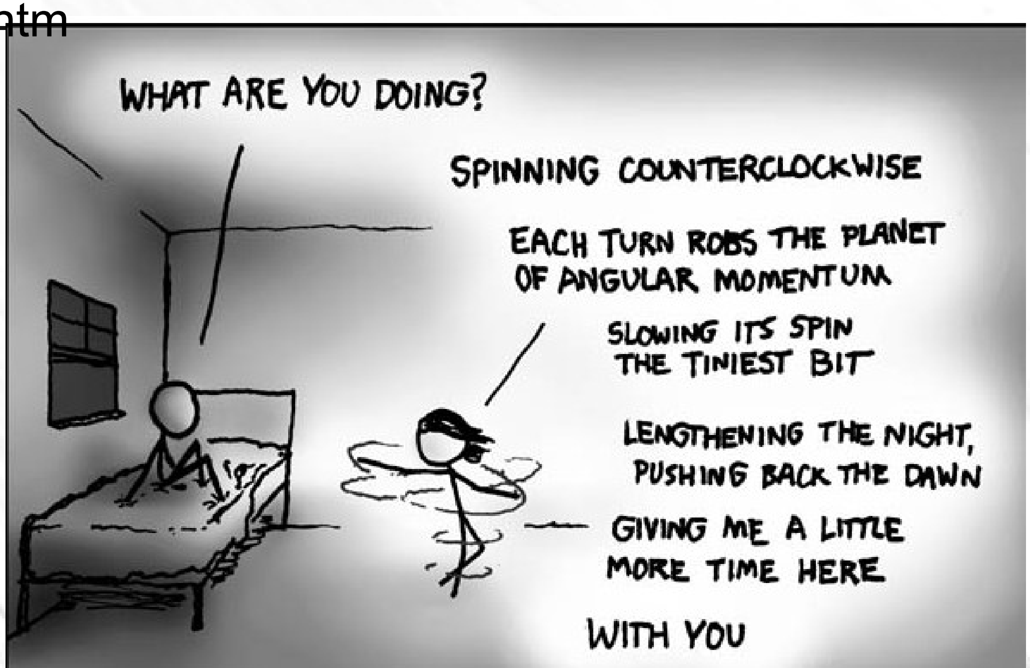


Which one wins ?



http://www.personal.psu.edu/djs75/cv.htm





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